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DRAW CONSTANT DOWNFEED PROCESS

FIELD OF THE INVENTION

The present invention relates to optical waveguide fibers, and more particularly, to methods for drawing an optical fiber from an optical fiber perform whereby the fiber exhibits a more uniform mode filed diameter (MFD) and reduced polarization mode dispersion (PMD).

BACKGROUND OF THE INVENTION

In the manufacture of optical fiber, a glass core preform is made which typically comprises SiO_2 , the axial portion of which is doped with a compound such as GeO_2 to increase the refractive index. When a fiber is drawn from the glass preform, the doped region will provide the light transmission portion or core of the fiber.

The above described process is well known in the art and will not be described in further detail. To obtain optical fiber the glass preform or blank is fed into a draw furnace heated to a melting temperature, and a small gob of glass, with a trailing fiber,

drops from the blank root. The fiber is fed to a tractor and capstan assembly which draws the fiber from the blank and the fiber is wound on a spool.

As fiber is drawn from a blank, the blank is fed into the furnace, and fiber diameter is closely monitored. Control of fiber diameter is generally accomplished by varying certain operating parameters at the draw tower. Typically, a fiber diameter measuring device is located just below the furnace outlet to measure the fiber diameter. The measured diameter is compared to a nominal diameter value and a signal is generated to either increase the tractor speed (thus decreasing the fiber diameter), or decrease the tractor speed (thus increasing the fiber diameter.)

In the 1970's and throughout the mid 1980's, blanks from which fiber was drawn were relatively small. Draw speeds did not exceed about 8 or 9 meters per second. Because of the blank size and draw speeds used, fiber diameter was controlled by varying the tractor speed while maintaining the furnace temperature and blank feed rate relatively constant.

In the mid- 1980's a new process control strategy was developed and introduced as a result of ever increasing draw speeds. Specifically, as draw speeds approached 10 meters/sec., those skilled in the art abandoned the use of constant downfeed rates. More specifically, it was believed that in order to achieve adequate control at high draw speeds, i.e. speeds approaching and in excess of 10 meters/sec., it was necessary to resort to a cascade or two-level process control strategy whereby, in response to an error signal indicating that the actual or measured fiber diameter was not equal to the desired diameter, there would be both a change in the draw speed and a change in the downfeed rate of the blank into the draw furnace. For example, if the measured fiber diameter was greater than the desired fiber diameter, then the control system would increase the tractor speed and, at the same time, decrease the rate at which the blank was fed into the draw furnace. This control philosophy reflected the belief that when operating a fiber draw process at a speed greater than 8-9 meters/sec., it was necessary to vary the blank

downfeed rate when draw speed was varied to maintain a more constant fiber diameter.

Although this two level control process results in an essentially constant fiber diameter it has been discovered that other detrimental effects occur as a result of this operation. It is believed that oscillations in the draw control loop, specifically, oscillations in the blank downfeed rate, can cause variations in the core shape during fiber formation. This may be particularly acute at the blank root from which fiber is drawn. It is believed that oscillations of the blank root in the furnace may affect the shape of the core as it is formed at the root of the blank, and this is believed to cause poor PMD and nonuniform MFD.

For optical fiber that will be used in telecommunication applications PMD should be as small as possible, and MFD should be maintained as uniform as possible. Several solutions have been proposed to address some of the problems mentioned above. For instance, commonly assigned and co-pending U.S. Patent Applications Nos. 08/858,836 and 08/784,574, and PCT Application No. PCT/US97/02541 disclose various methods and apparatus for imparting spin to the fiber as it is drawn to reduce PMD. Spinning optical fiber as it is drawn causes internal geometric and/or stress asymmetries of the fiber to rotate about the fibers axis along the length of the axis; however, spinning the fiber does not address the underlying problems in the glass that cause PMD, nor does spinning entirely eliminate PMD or address the issue of MFD uniformity.

In view of the disadvantages in the art, it would be desirable to provide a method for maintaining or increasing MFD uniformity while at the same time reducing PMD. There is an explicit need for such when drawing optical fiber at high draw rates, i.e. greater than 10 meters/second, which may contribute to increased downfeed oscillation in the root, there by increasing PMD in the fiber.

SUMMARY OF THE INVENTION

Accordingly, the present invention is directed to a method for the high speed drawing of optical fiber that alleviates one or more of the problems due to limitations and disadvantages of the related prior art. The principal advantage of the present invention is the provision of a method for controlling the diameter of a drawn optical fiber while reducing PMD in the fiber and maintaining uniform MFD when drawing the fiber at high speed. The method comprises drawing fiber at a high speed while keeping the blank downfeed rate constant. It is believed that constant downfeed rate avoids oscillation of the blank root in the furnace which causes variability in the core shape during fiber formation. Such variations are believed to contribute to poor PMD and MFD in the final fiber.

To achieve these and other advantages and in accordance with the purpose of the invention, as embodied and broadly described, the invention is a method for reducing polarization mode dispersion in drawn optical fiber comprising the steps of feeding an optical fiber preform of a predetermined size into a furnace at a predetermined downfeed rate, drawing an optical fiber from the optical fiber preform at a draw rate of at least 10 meters per second, and varying the draw rate to maintain a substantially constant fiber diameter while maintaining the predetermined downfeed rate constant. Preferably, the draw rate is greater than 14 meters per second and most preferably, greater than 20 meters per second.

In a preferred embodiment, the downfeed rate is constant for a first zone or range of draw speeds and is then changed to a different constant downfeed rate for a second zone or range of draw speeds. As the draw speed varies in each zone, the downfeed rate remains constant within each zone. In addition, the downfeed rate may be different for each zone. The method may also include the step of decreasing the downfeed rate as the draw rate changes from one zone to another having a higher rate of draw speeds, or increasing the downfeed rate as the draw rate changes from one to another

having a lower range of draw speeds. The invention may also include the step of spinning the fiber as it is being drawn to further reduce PMD.

In accordance with another embodiment of the invention, a method for drawing optical fiber from an optical fiber preform is provided, comprising the steps of feeding the optical fiber preform of a predetermined size into a draw furnace at a constant downfeed rate and drawing optical fiber from the optical fiber preform at a draw rate of at least 10 meters per second. The method further comprises the steps of measuring the drawn fiber diameter and generating a signal representative of the measured diameter and comparing the generated signal to a nominal fiber diameter. A second signal representative of the difference of the comparison is generated and used to vary the draw rate to adjust the drawn fiber diameters. The method also includes the step of sensing the draw rate to determine if it is within a zone of predetermined speeds and changing the downfeed rate to another predetermined rate if the sensed draw rate is outside of the zone. The downfeed rate is constant for a first zone or range of draw speeds and is then changed to a different constant downfeed rate for a second zone or range of draw speeds. Preferably, the downfeed rate is maintained constant within each zone and as the draw rate is varied between the plurality of zones, the downfeed rate is change accordingly. The method according to this embodiment may include the further step of spinning the optical fiber as it is drawn.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic diagram of a fiber drawing apparatus.

DETAILED DESCRIPTION

The present invention is directed to method for reducing polarization mode dispersion in drawn optical fiber wherein an optical fiber preform of a predetermined size is fed into a furnace at a predetermined downfeed rate. Preferably, the downfeed rate is kept constant throughout the entire draw process in order to minimize oscillation of the preform root in the furnace in order to maintain MFD uniformity and reduce PMD in the drawn optical fiber.

Fig. 1 illustrates a well known optical fiber draw system, designated generally by reference numeral 1. Preform 10 disposed vertically in muffle 11 of a draw furnace. Preform 10 includes a handle (not shown) that attaches to a holding device (not shown) in a known manner. The holding device is part of preform feed drive 22, which controls the rate at which preform 10 is fed into the furnace. Heating element 12 supplies heat to at least the bottom portion of preform 10. The temperature of heating element 12 is controlled by temperature controller 49 in a known manner. After a well known start up procedure is employed, preform feed drive 22 feeds preform 10 into the furnace. As preform 10 is fed into the furnace, the end portion of preform 10, commonly referred to as the root, melts and fiber 14 is drawn from root portion 13 of perform 10 by tractor 20.

After leaving muffle 11, fiber 14 passes through diameter monitor 15 which produces a signal that is used in a feedback control loop to regulate the speed of tractor 20 and preform feed drive 22, as well as to regulate temperature in the furnace through temperature controller 49. After diameter monitor 15, fiber 14 passes through a cooling tube 17 and a coater 18 by which a curable protective coating is applied to fiber 14. The coated fiber may also pass through a coating curing apparatus and if desired additional coaters (not shown). The feedback control of perform feed drive 22, tractor drive 21 and temperature controller 49 can be implemented by known control algorithms. Tractor drive 21 is provided with an input from control algorithm 48 which is part of draw control computer 47. Given the demand for optical fiber, it is advantageous to run tractor 20 at a rate of at least 10 meters per second.

Preferably, tractor 20 produces a draw speed of greater than 14 meters/second, and more preferably greater than 20 meters per second.

The present invention is directed to a method for reducing polarization mode dispersion in drawn optical fiber comprising the step of feeding a glass preform and drawing an optical fiber at a speed greater than 10 meters/second. The size of preform 10 can be measured by weight or by its diameter. The downfeed rate of perform 10 is selected based on the size of perform 10. Preferably, the downfeed rate, once selected, remains constant throughout the fiber drawing process. Alternatively, the downfeed rate may remain constant within a predetermined zone or range of draw speeds. There may be any number of zones of draw speeds and the range of draw speeds within each zone may also vary. However, each zone has a predetermined downfeed rate associated with it and the downfeed rate remains constant within the given zone.

If the draw speed, which is controlled through tractor drive 21, increases or decreases out of a specific zone of draw speed, a signal is sent from control algorithm 48 to preform feed drive 22 to change the downfeed rate to the appropriate downfeed rate for the particular zone of draw speed. Control algorithm 48 is set up so that as the tractor speed changes from one zone to another, the downfeed rate changes by small increments until the predetermined downfeed rate is reached. This allows the downfeed rate to adjust back to the original rate quickly if the tractor speed were to suddenly return to the original zone.

According to another aspect of the invention, the method may comprise the further steps of sensing the draw rate to determine if it is within a zone of predetermined speed and varying the downfeed rate if the sensed draw rate is outside of the zone. In this embodiment, a draw rate sensor (not shown) continually monitors draw rate at draw control computer 47. If the draw speed changes from one zone to another, control algorithm 48 sends a signal to preform feed drive 22 to increase or decrease the downfeed rate to the predetermined constant rate associate with the zone of draw speed.

The present inventive method also includes the step of varying the draw rate in response to the measured fiber diameter to maintain a substantially constant fiber diameter while maintaining the predetermined downfeed rate constant. In order to maintain a constant fiber diameter, fiber 14 is constantly monitored by diameter monitor 15. Diameter monitor 15 produces a signal representative of the measured fiber diameter. That signal is sent to draw control computer 47. At draw computer 47, the measured signal is compared to a predetermined nominal fiber diameter value. A second signal is generated based on any difference between the measured fiber diameter value. The second signal sent to the tractor drive 21 and the tractor speed is varied to maintain a constant fiber diameter. This process is carried out hundreds of times per minute and the downfeed rate remains constant throughout the draw process during all ranges of tractor speed.

It may also be advantageous to spin the fiber as it is drawn. Spin in fiber has been demonstrated to further reduce PMD. Various methods and apparatus have been developed to impart spin in a fiber as it is drawn. Reference is made to commonly assigned and co-pending U.S. Patent Applications Nos. 08/858,836 and 08/784,574 and PCT application no. PCT/US97/02541; and U.S. Patent No. 5,298,047, for a more detailed understanding of methods and apparatus used for spinning fiber, each of which is herein incorporated by reference.

The advantages associated with the invention are numerous. In the prior art draw systems, fiber diameter is controlled by tractor speed. The control loop involves a two step process control at the draw . If the tractor speed varies, the downfeed rate responds to variation in tractor speed. Although not wanting to be bound by any theory or explanation as to why the present invention functions, we believe that this in turn produces an oscillation of root 13 in the furnace. It is believed that oscillation of the root portion of preform 10 in the furnace causes variability in the core shape of the draw optical fiber and that the variations in core shape lead to higher PMD and nonuniformity in MFD, both of which adversely affect fiber performance.

The present invention helps to reduce preform oscillation by providing a constant down feed rate during the draw process. Contrary to the well-recognized two-step control approach to drawing fiber at high rates of speed, control algorithm 48 is set up to maintain the preform downfeed rate constant even as the tractor speed varies to maintain fiber diameter. It is believed that this control mechanism reduces or perhaps eliminates oscillations in the draw control loop that can cause variations in the core shape during fiber formation, and results in reduced PMD and improves MFD uniformity.

EXAMPLES

The invention will be further described by the following examples, which are intended to be exemplary of the invention.

EXAMPLE 1

An unspun optical fiber was produced using a draw system similar to that illustrated in Fig. 1. The tractor speed was allowed to vary up to a maximum of 19 meters per second to maintain a constant fiber diameter, while the downfeed rate was kept constant at about 2.75 millimeters per minute. The resulting fiber was tested for PMD and MFD uniformity. The results as compared to a fiber drawn under a standard process (i.e. variable downfeed rate), are shown in Table 1 below:

Table 1

	CONSTANT DOWNFEED RATE
% REDUCTION PMD	71%
%IMPROVEMENT MFD UNIFORMITY	83%

As the results indicate, PMD was significantly reduced and MFD was improved in the draw process according to the present invention compared to a standard process.

EXAMPLE 2

A fiber was drawn using an apparatus similar to that depicted in Fig. 1 The fiber was also spun during the draw process. The downfeed rates were set according to the zone embodiment of the present invention as describe above to achieve a 15.5 meters per second nominal draw speed. The drawn fiber was tested and the results of PMD and MFD uniformity were compared to a fiber drawn using a standard draw process. Several different runs were undertaken and the results are shown in Table 2 below.

Table 2

	CONSTANT DOWNFEED RATE
% REDUCTION PMD	80%
% IMPROVEMENT MFD UNIFORMITY	76%

As Table 2 shows, there is a significant reduction in PMD in fibers drawn according to the present invention as compared to the fibers drawn

according to a standard process. MFD uniformity is also significantly improved.

It will be apparent to those skilled in the art that various modifications and variations can be made in the method of the present invention which are nevertheless within the scope of the appended claims and their equivalents.